Evaluation of the Impact of Satellite Radiance Data Within the Hourly Rapid Refresh Data Assimilation System

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BACKGROUND

- Challenges for regional, rapid updating radiance assimilation
  - Bias correction (difficulty due to non-uniform data coverage and smaller domain)
  - Lower model top (10-hPa for the RAP; channel selection)
  - Data availability issues for real-time use
    - Large data latency especially for polar-orbital satellites
    - Short data cut-off time of hourly system (~35 min)
    - Complicates bias correction
    - Direct readout data
- Goal: Evaluate the impact of real-time radiance data on the hourly Rapid Refresh (RAP) mesoscale prediction systems; examine ways to maximize the very short-term forecast using the satellite radiance data; compare the impact of radiance data with other data sets within the RAP.

RAP and HRRR

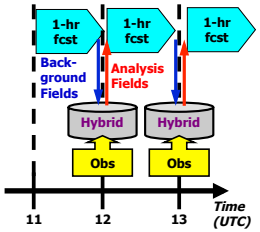
Hourly updated assimilation/model system using GSI analysis and WRF ARW model

Version 2 (EnKF hybrid) -- NCEP implemented 25 Feb 2014

Version 3 – GSD
Planned NCEP – Aug 2015
Larger Domain (red → white)
Longer Forecasts

HRRR Initial – NCEP
implemented 30 Sept 2014
Version 2 – GSD
Planned NCEP – August 2015
Longer Forecasts

Rapid Refresh



Data types – counts/hr

Rawinsonde (12h)	150
NOAA profilers	35
VAD winds	~130
PBL profilers / RASS	~25
Aircraft (V,T)	3500–10,000
TAMDAR	200 – 3000
METAR surface	2000 -2500
Mesonet (T,Td)	~8000
Mesonet (V)	~4000
Buoy / ship	200-400
GOES cloud winds	4000-8000
METAR cloud/vis/wx	~1800
GOES cloud-top P,T	10 km res.
satellite radiance	AMSUA/MHS/HIRS/ GOES RARS
Radar reflectivity	1 km res.

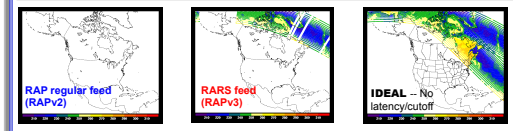
RAPv3 radiance updates

- Implement the enhanced variational bias correction scheme (developed by EMC/NCEP) with cycling;
- Remove some high-peaking channels to fit the model top of the RAP and O_3 channels;
- Include the direct readout (Regional ATOVS Retransmission Services (RARS)) data;
- Include new sensors/data (GOES-15, AMSU-A/MHS from NOAA-19, METOP-B).

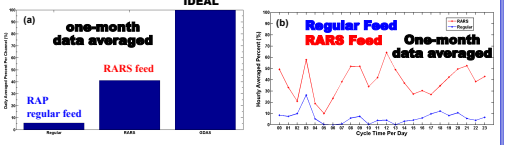
Satellite	Sensor	Channels assimilated
NOAA-15	AMSU-A	1-10, and 15
NOAA-18	AMSU-A	1-8, 10 and 15
	MHS	1-5
NOAA-19	AMSU-A	1-7, 9-10 and 15
METOP-A	AMSU-A	1-6, 8-10 and 15
	MHS	1-5
	HIRS-4	4-8 and 10-15
GOES-15	sndrD1/sndrD2/sndrD3/sndrD4	3-8 and 10-15

List of AMSU-A, MHS, HIRS4, and GOES radiance channels used in RAPv3 and the retro runs

Real-time Radiance Coverage within RAP

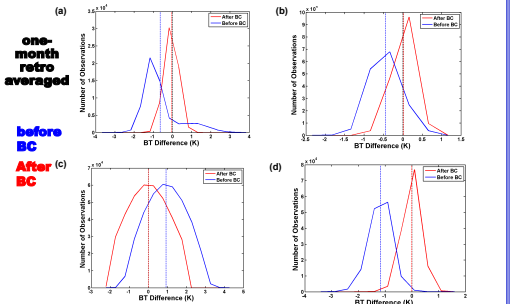


RAP data coverage of AMSU-A channel 3 from NOAA-18 on 18Z May 29, 2013 (+/- 1.5 h time window)



(a) Daily averaged percent (%) and (b) hourly averaged observation percent for regular feed and RARS feed against ideal conditions. Statistics are computed from NOAA-18 AMSU-A channel 3 over the RAP domain over a one-month period (05/01/2013-05/31/2013). The time window is +/- 1.5 hour.

Bias Correction Evaluation



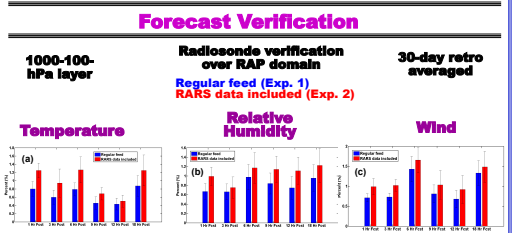
Histogram of BT O-B before BC and after BC for (a) amsua channel 4 on NOAA-15, (b) HIRS4 channel 5 on metop-a, (c) mhs channel 3 on NOAA-18, and (d) sndrD1 channel 14 on GOES-15. Statistics are computed from the one-month (May 2013) retrospective run.

Experiment Set I

Goal: Evaluate the impact of radiance data within full mix of observations and the additional benefits of the direct readout data

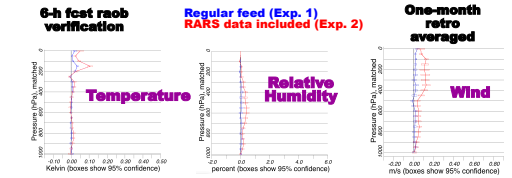
Control: conventional data only (2013/05/01-2013/05/31)
Experiment I: control + regular radiance feed data (RAPv2 data)
Experiment 2: experiment 1 + RARS feed data (RAPv3 data)

Forecast Verification



Normalized error reduction [(CNTL – EXP)/CNTL] (%) from RAP real time regular feed data (blue), real time data plus RARS feed data (red), for (a) temperature, (b) relative humidity, and (c) wind. The control run uses conventional data only. Statistics are computed for 1000-100-hPa layer over the RAP domain. The retrospective period is from May 01 to May 31, 2013. The error bar indicates the ±1.96 standard error from the mean impact, representing the 95% confidence threshold for significance.

Experiment Set I (continued)



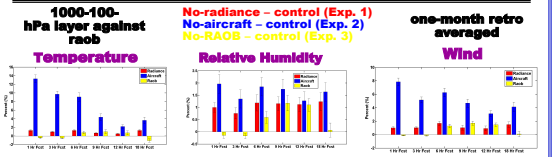
RMS error difference against radiosonde for 6-h forecast between Exp. 1 (blue, regular feed radiance included) and the control run, Exp. 2 (red, RARS feed included) and the control run for (a) temperature; (b) relative humidity; and (c) wind. The positive values indicate the radiance run is superior than the control run while the boxes indicate the ±1.96 standard errors from the mean, representing the 95% confidence threshold for significance. Statistics are computed over one-month run across the RAP domain.

Experiment Set II

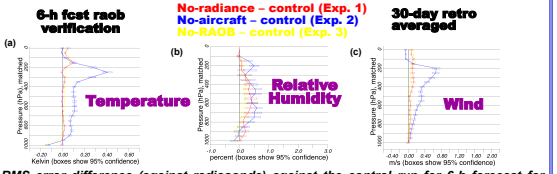
Goal: Evaluate the impact comparison of radiance data with aircraft and radiosonde data sets within the RAP mix of observations

Control: All data (conventional + radiance (including RARS data) (2013/05/01-2013/05/31)
Experiment I: all satellite radiance data denial
Experiment 2: aircraft data denial
Experiment 3: radiosonde data denial

Forecast Verification



Normalized error reduction [(EXP – CNTL)/CNTL] (%) from Exp. 1 (radiance denial, red), Exp. 2 (aircraft denial, blue), and Exp. 3 (raob denial, yellow) for (a) temperature, (b) relative humidity, and (c) wind. The control run uses all data. Statistics are computed for 1000-100-hPa layer over the RAP domain. The retrospective period is from May 01 to May 31, 2013. The error bar indicates the ±1.96 standard error from the mean impact, representing the 95% confidence threshold for significance.



RMS error difference (against radiosonde) against the control run for 6-h forecast for Exp. 1 (red, radiance data denial), Exp. 2 (blue, aircraft data denial), and Exp. 3 (yellow, raob denial) for (a) temperature; (b) relative humidity; and (c) wind. The positive values indicate positive impact if this data set is included while the boxes indicate the ±1.96 standard errors from the mean, representing the 95% confidence threshold for significance. Statistics are computed over a one-month run across the RAP domain.

SUMMARY AND FUTURE WORK

Summary:

- A series of radiance updates have been tested at ESRL/GSD and will be implemented on operational RAPv3 in August 2015.
- A 1-1.5% positive impact (statistically significant) has been seen for temperature, moisture, and wind for all forecast hours in the RAP with the full mix of observation.
- The radiance data impact is comparable to the raob data impact, but less than the aircraft data impact.
- Direct readout data is especially important to the hourly RAP.

Future work:

- Include more direct readout data in real-time RAP and continue to test and evaluate their impact in RAP;
- Include new data such as data from GOES-R ABI;
- Increase RAP model top and model levels.